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6. AUTHORS

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14. ABSTRACT

During the course of this research we have developed techniques for practical implementation of electron spin resonance in quantum dots. These include a specialized mount for application of rf magnetic fields to drive electron spin resonance, on-chip matching networks for quantum point contacts and single electron transistors, and integrated nanomagnets that give rise to a field differential between two adjacent dots. We have also developed shot-noise-limited radio-frequency quantum point contacts and near-quantum limited radio frequency single

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Quantum dot, electron spin resonance, quantum point contact

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Report Title

Practical Implementation of Electron Spin Resonance in Quantum Dots: Final Report

ABSTRACT

During the course of this research we have developed techniques for practical implementation of electron spin resonance in quantum dots. These include a specialized mount for application of rf magnetic fields to drive electron spin resonance, on-chip matching networks for quantum point contacts and single electron transistors, and integrated nanomagnets that give rise to a field differential between two adjacent dots. We have also developed shot-noise-limited radio-frequency quantum point contacts and near-quantum limited radio frequency single electron transistors for charge readout.

List of papers submitted or published that acknowledge ARO support during this reporting period. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

"Near-Quantum-Limited Operation of a Charge-Sensitive Electrical Amplifier," A. J. Rimberg, W. W. Xue, Z. Ji, F. Pan and J. Stettenheim, IEEE Trans. Nanotechnol., in press.

"A Macroscopic Mechanical Resonator Driven by Mesoscopic Electrical Backaction," J. Stettenheim, M. Thalakulam, F. Pan, M. Bal, Z. Ji, W. W. Xue, L. Pfeiffer, K. W. West, M. P. Blencowe, and A. J. Rimberg, Nature 466, 86 (2010).

"Measurement of Quantum Noise in a Single Electron Transistor Near the Quantum Limit," W. W. Xue, Z. Ji, F. Pan, J. Stettenheim, M. P. Blencowe and A. J. Rimberg, Nature Phys. 5, 660 (2009).

"On-Chip Matching Networks for Radio-Frequency Single-Electron Transistors," W. W. Xue, B. Davis, Feng Pan, J. Stettenheim, T. J. Gilheart, A. J. Rimberg and Z. Ji, Appl. Phys. Lett. 91, 093511 (2007).

Number of Papers published in peer-reviewed journals: 4.00

(b) Papers published in non-peer-reviewed journals or in conference proceedings (N/A for none)

"The Quantum Limit for Electrical Amplifiers: Can We Reach It'" A. J. Rimberg, W. W. Xue, Z. Ji, F. Pan, J. Stettenheim, and T. J. Gilheart, Proceedings of the SPIE, 6885, 688505 (2008).

Number of Papers published in non peer-reviewed journals: 1.00

(c) Presentations

Number of Presentations: 0.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts): 0

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts): 0

(d) Manuscripts

Number of Manuscripts: 0.00

Patents Submitted

Patents Awarded

Awards

Graduate Students

NAME	PERCENT_SUPPORTED
Weiwei Xue	1.00
Joel Stettenheim	1.00
FTE Equivalent:	**2.00**
Total Number:	**2**

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

NAME	PERCENT_SUPPORTED	National Academy Member
Alex Rimberg	0.08	No
FTE Equivalent:	**0.08**	
Total Number:	**1**	

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period:	0.00
The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:......	0.00
The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:......	0.00
Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):......	0.00
Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:......	0.00
The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense	0.00
The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:	0.00

Names of Personnel receiving masters degrees

NAME

Total Number:

Names of personnel receiving PHDs

NAME	
Weiwei Xue	
Total Number:	**1**

Names of other research staff

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Sub Contractors (DD882)

Inventions (DD882)

Final Report—April 2010

During the course of this grant, significant progress was made toward our goal of using low-electric field electron spin resonance (ESR) for coherent manipulation of electron spins in GaAs and SiGe quantum dots. We have developed the fabrication techniques needed to produce double quantum dots in GaAs or Si/SiGe that include both an integrated nanomagnet as well as an integrated radio-frequency single electron transistor (RF-SET) or quantum point contact. This required development of techniques for alignment of multiple electron-beam lithography steps with an accuracy of a few tens of nanometers. Furthermore, each sample includes an on-chip superconducting spiral that will be used for impedance matching of the charge detector to external rf circuitry. A typical sample geometry is shown in Fig. 1 below.

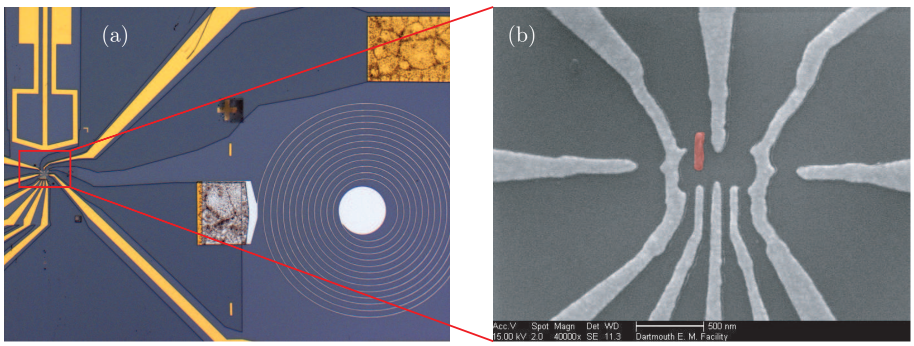

Figure 1: (a) Optical micrograph of a DQD with on-chip superconducting spiral to be used as a matching network. (b) Electron micrograph of the DQD, showing both the nanomagnet (red) and nearby QPC charge detectors.

Several samples similar to that in Fig. 1 have been tested over the last several months. Preliminary measurements indicate that the nanomagnet likely acts as a floating gate an partially depletes the electron gas beneath it when nearby gates are energized, interfering with transport measurements. A new gate pattern has been devised that moves the nanomagnet further from the QPC on the left dot in the DQD, and increases the dot area somewhat so that the magnet is farther from the surrounding gates.

In addition to development of sophisticated sample fabrication techniques, a customized mount for application of low-electric-field ESR fields was developed and characterized. Techniques for aligning the sample to the ESR mount were developed that allow positioning of the sample within a few microns both vertically and laterally of the maximum in the ESR field were also developed. A DQD sample with an integrated SET charge detector is currently being measured with the intent of testing the performance of the ESR mount under actual operating conditions.

Our effort related to production of Si/SiGe based quantum dots have also progressed rapidly in the last year. We have now produced several working Si/SiGe dots with low-leakage Schottky gates that have dramatically improved our yield. As a result, we are in a position to begin integrating SETs with our Si/SiGe dots as well. Such samples are actively being fabricated and tested as of this writing.

Finally, in the process of testing RF-QPCs for use as charge detectors in GaAs-based dots, we discovered that the backaction of the tunneling electrons in such a QPC can couple to a naturally-occurring vibrational mode in GaAs samples. This electromechanical coupling leads to important consequences for both the QPC and the mechanical resonator (the GaAs sample). Correlations for the tunneling electrons are strongly affected by the coupling, resulting in the presence of both

strongly super-Poissonian and significantly sub-Poissonian shot noise. Furthermore, the classical dynamics of the oscillator are strongly non-thermal, and in fact are completely dominate by the backaction of the tunneling electrons. A manuscript based on these results was recently accepted for publication in Nature.

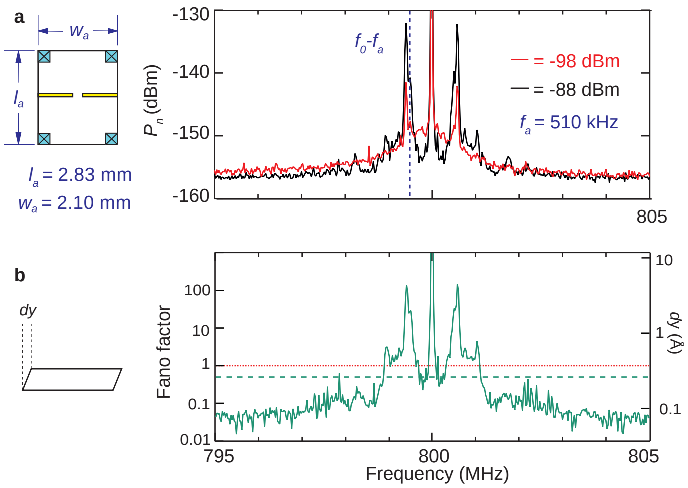

Figure 2: (a) Shot noise of a quantum point contact (QPC) in a resonant circuit. The noise shows sharp features due to coupling to a resonant mechanical mode of the QPC substrate. (b) Fano factor of the QPC shot noise, showing strong modulation of electrical noise due to electromechanical coupling to the substrate, one of the few unambiguous experimental demonstrations of such an effect.